Naval Submarine Medical Research Laboratory

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Summary: Disabled Submarine Heat Stress Conference 22 June 2004

Wayne G. Horn, M.D.

Approved and Released by:
D.G. SOUTHERLAND, CAPT, MC, USN
Commanding Officer
NAVSUBMEDRSCHLAB

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14. ABSTRACT

Two submarine survival exercises revealed the potential for heat stress in disabled submarine (DISSUB) scenarios. This conference convened a panel of recognized heat stress experts for recommendations to address the issue of DISSUB heat, its effects on survivors, and mitigation efforts. Heat conditions and heat stress are major factors in disabled submarine survival. Planning and preparations for DISSUB survival should include consideration of procedures and equipment to deal with heat conditions.

15. SUBJECT TERMS

Heat stress, heat injury, disabled submarine, submarine, submarine survival, heat injury mitigation, hyperthermia

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Wayne G. Horn, M.D.

Naval Submarine Medical Research Laboratory

Approved and Released by:

CAPT D.G. Southerland, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory
Submarine Base New London Box 900
Groton, CT 06349-5900

Administrative information

The views expressed in this report are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the United States Government.

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SUMMARY: DISABLED SUBMARINE HEAT STRESS CONFERENCE

Naval Submarine Medical Research Laboratory
22 June 2004.

Chair: CDR Wayne G. Horn
Attendees: Appendix A
Agenda: Appendix B

Initial remarks

CDR Wayne Horn began the conference with opening remarks, followed by a PowerPoint presentation outlining the current status of the submarine force, submarine rescue and asset capabilities, and the potential for heat stress development in disabled submarine scenarios. Main points brought out in the presentation and following discussion included heat causes and heat transfer in DISSUBs and the limited ability of crewmembers to address heat in the boat by other than escaping.

Heat Stress Measurement

In discussion of heat stress measurement, the consensus of the panel was that standard wet globe bulb temperature devices were not needed in DISSUB conditions, since radiation (no solar load) was not a significant factor. In DISSUB conditions only two factors need determination: ambient heat and humidity. These parameters can be measured by several methods: temperature by dry bulb thermometer and humidity using either a sling psychrometer or a portable battery-powered electronic device providing a direct readout of measurements.

In examining the need for a device that could be stored for years until needed, the panel suggested small portable devices that cost several hundred dollars and were reasonably accurate, such as a Kestrel hygrometer. Dr. Kolka and Mr. Heaney agreed to provide a list of commercially available devices, with specifications, that would address the needs of low cost, reasonable accuracy, long shelf life, minimal or no calibration, low maintenance and battery change requirements, and at least 7-day performance in actual use.

CDR David Horn said that submarines normally carried one WGBT instrument but that many carried two, with the second as a spare. There is currently no designated stowage location for the WGBT device. This is a deficiency in DISSUB preparedness in that each compartment needs an instrument available.

Several options for providing DISSUB temperature and humidity determinations appear viable:

1) One WGBT device available in each compartment.

2) One dry bulb thermometer and sling psychrometer in each compartment

3) One battery-powered electronic thermometer/hygrometer in each compartment

Heat Stress When-To-Escape Guidance

Determination of safe-to-stay, when-to-escape conditions was discussed at length. Dr. Sawka produced a chart (Appendix C) of temperature/humidity conditions that he recommended, with others in agreement, for use in DISSUB conditions. This chart, which graphs wet and dry bulb temperatures, sets forth effective temperature zones of comfort, discomfort, and temperature regulation failure. Entry of the wet and dry bulb readings permits determination of the zone of comfort/discomfort and a corresponding when-to-escape decision.

Physiological Monitoring

In DISSUB scenarios, cognition and hypotension are the most critical factors and significant effects relevant to heat stress assessment and physiological functioning. Of the two, hypotension is most likely the first affected in hot DISSUB conditions.

Hypotension secondary to dehydration will probably not be detected in DISSUB scenarios until survivors stand up after emerging from their bunks. For this reason, DISSUB crew members should stand and walk briefly about their space every two hours when not asleep. This action is a test of hydration status as well as preventing soreness from excessive time in the bunk. The panel recommended a two-hour time interval based on roving watch schedules and onset of symptoms. Two hours is a reasonable compromise given anticipated DISSUB conditions. Crew members emerging from a topmost rack need observation and assistance when emerging to avoid injury if syncope occurs. For this reason a buddy system of paired or three members in a group would improve observation and prevent injuries. Comparison of supine, sitting and standing blood pressures provides an effective indicator of hypotension.

Cognition is also an important factor as a symptom of heat stress. It is also required for effective functioning in disabled submarines in that on board duties and the performance of escape require reasonable cognitive functioning. Brief, reasonably accurate tests of mental status are readily available.

In DISSUB conditions, increases in body core temperature prior to the observation of dehydration symptomatology are unlikely unless extreme conditions of heat and humidity develop in the DISSUB. Monitoring a large number of survivors closely in DISSUB conditions is difficult and not recommended by the panel, both for survival exercise and actual DISSUB scenarios.

The panel members felt that a check of daily weights and monitoring for weight loss provided the best screening for onset of heat stress-induced dehydration. The sudden loss of one to two pounds or more would, in day-to-day DISSUB conditions, be highly suggestive of dehydration. An accurate scale placed in the mess decks and used just prior to eating would meet this goal. The panel felt that specific gravities were not an effective screen in view of lack of sensitivity of hydration status. Similarly, core temperatures would likewise be impractical to obtain in large numbers of test subjects or DISSUB survivors.

DISSUB Survivor Water Requirements

The panel members discussed water requirements after discussion of DISSUB conditions. The consensus of the panel was that one liter of water per day was the minimal requirement but that in hot conditions up to four liters or more of water per day might be required for optimal hydration. The simple recommendation is one quart every six hours. Hydration while eating was also recommended.

Salt tablets were specifically not recommended. Salt obtained from salty foods was preferred. Also, commercially available "Astro-aid", developed by John Greenleaf, a hypertonic powder mix that can be taken prior to escape. This has proven to be effective in preventing hypotension in NASA astronauts on return to Earth from prolonged space flight. Adequate hydration is important in maintaining blood pressure. It also reduces the risk of decompression illness after rescue or escape.

Panel members recommend that each survivor maintain a personal log noting voids, food intake and water intake. This action permits self-assessment by survivors and a written log for quicker review by monitors and care providers.

Personal Cooling Strategies

As a general heat stress mitigating action, limb immersion in cool or even ambient temperature water may provide substantial heat stress relief in terms of both providing comfort and reducing core temperature. Limb immersion in cool water for one to ten minutes provides this effect. The preferred method is hand and forearm immersion in the coolest water obtainable. However, the feet and lower extremities may also be immersed. Ice or packaged frozen food items can be used to lower water temperature. Likewise, packaged items from the boat's frozen or chilled food storage can be placed against protected skin to lower body temperature.

Placement of cool packs for heat mitigation should be in the forearm, feet, head or axillae. Men should maintain their conditions in their bunks with shoes off in the rack. Shoes should be worn when moving about the boat. DISSUB clothing guidance is simply to dress for comfort. This may require stripping to underwear.

Misting is not recommended since it provides little effective relief in humid DISSUB conditions and increases humidity in the boat.

Heat acclimatization will be slow to occur and is not apt to provide physiological adaptation to DISSUB conditions in the 7-day escape/rescue timeline.

DISSUB Heat Stress Casualty Treatment

The development of hypotension or confusion in a DISSUB crewmember may have causes other than dehydration which deserve investigation or consideration. Principal components of heat stress casualty treatment in DISSUB scenarios include delivery of fluids, orally or intravenously, and reducing body heat.

Oral rehydration is recommended by the panel as the preferred rehydration technique. Drinking normal saline solutions is an effective hydration solution but in some cases may cause vomiting. Intravenous replacement should be used only if oral rehydration is not possible.

Heat stress casualties should be cooled by placing cotton sheets on patients and soaking the sheets in cold water. Cooling can also be facilitated by generating local air movement by fanning. In DISSUBs, a small number of patients can be placed on the mess deck and wardroom tables.

A low number of dehydration casualties may permit delivery of IV fluids and monitoring core temperatures. However, heat casualties are apt to occur in clusters. A larger number of survivors may reduce time and effort available to provide intensive care needed for heat stress casualties. This is due to the presence of only one health care provider, the submarine IDC, who also may not be among the survivors.

Other Conclusions

The onset of heat casualties should either initiate or demand strong consideration of escape.

For the purposes of heat stress management and treatment, there are no essential differences between men and women. For women in disabled submarines, no gender-specific changes in heat stress management or considerations are required.

APPENDIX A

Attendees
DISSUB Heat Stress Conference
22 June 2004

Name	Command
CDR Wayne Horn	Naval Submarine Medical Research Laboratory
Surg. CDR Peter Benton, RN	Naval Submarine Medical Research Laboratory
Dr. David Fothergill	Naval Submarine Medical Research Laboratory
HMCS(SS) Michael Napolitano	Naval Submarine Medical Research Laboratory
Mr. Jay Heaney	Naval Health Research Center
CDR David Horn	Board of Inspection and Survey
Dr. Michael Sawka	US Army Research Institute for Environmental Medicine
Dr. Lou Stephenson	US Army Research Institute for Environmental Medicine
Dr. Margaret Kolka	US Army Research Institute for Environmental Medicine
Capt Robert Carter , USA	US Army Research Institute for Environmental Medicine
Dr. John Muller	Naval Environmental Health Center
LCDR Wallace Schlauder	COMSUBRON 4

APPENDIX B

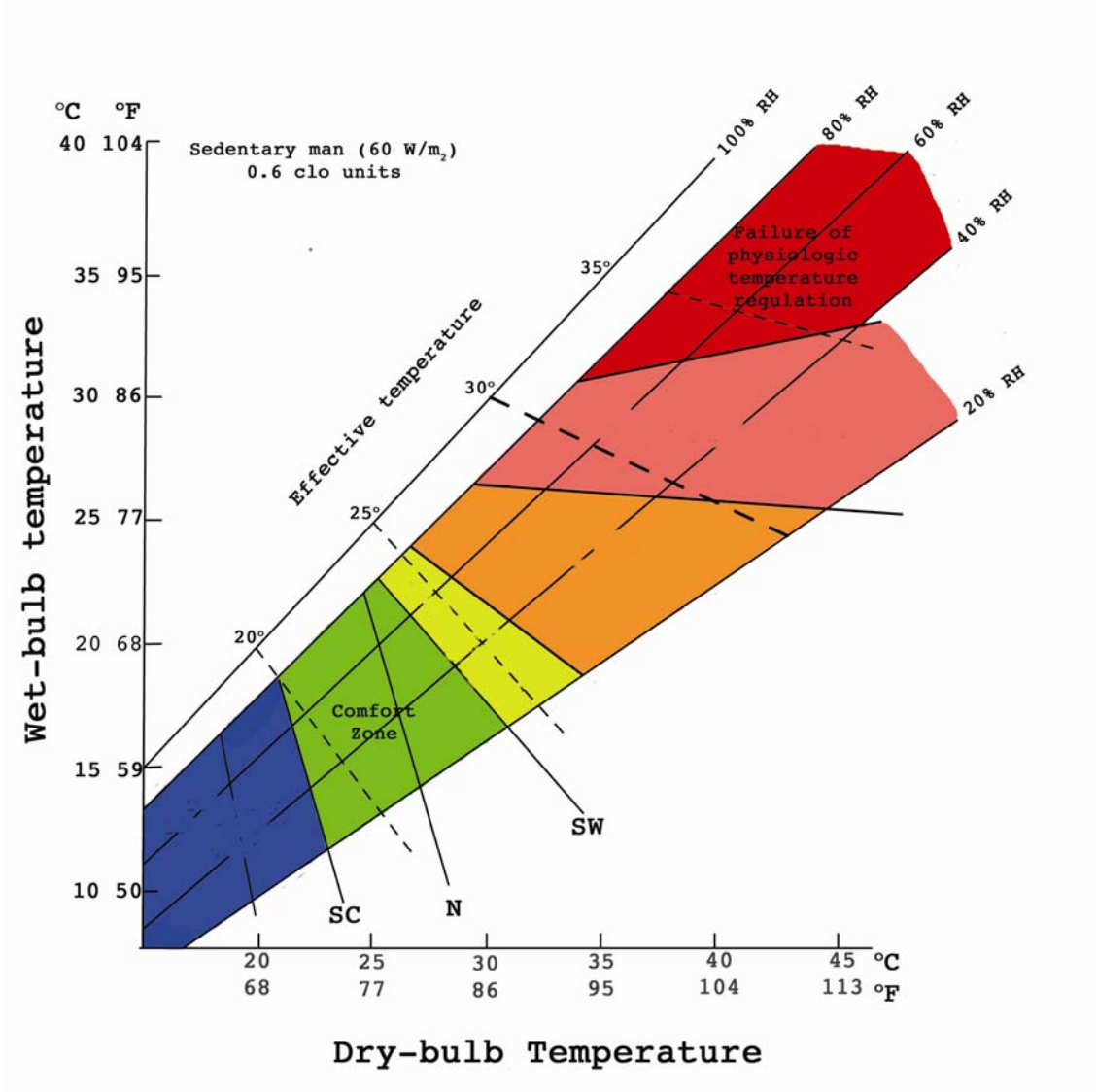
- AGENDA -
Disabled Submarine Heat Stress Conference
22 June 2004

Venue: Bldg 156, 2nd Deck Conference Room
Naval Submarine Medical Research Laboratory
(short walk from the Susse Chalet Hotel & BOQ)

22 June 2004

0800	Coffee/Pastries/Fruit	
0815	Opening Remarks/Submarine Presentation	Commander Wayne Horn, MC, USNR
0820	DISSUB Heat Stress Problem Outline	Commander Wayne Horn, MC, USNR
0845	Heat Stress Measurement Instrumentation, WGBT, other devices Other techniques Calculations	Panel Discussion
0945	**BREAK**	
1000	Heat Stress Guidance Determination of safe-to-stay, when-to-escape-by conditions Formulae, graph, table development	
1200	**LUNCH**	
1230	Physiological Monitoring Urinary Output Other Fluid Intake	
1330	Personal Cooling Strategies Spray or immersion Clothing recommendations	
1400	**BREAK**	
1415	Treatment of DISSUB heat stress casualties	
1445	DISSUB heat mitigating measures Flooding Predicting cool areas Insulation removal	
1600	Recommendations for further action	
1630	**ADJOURN**	

APPENDIX C


°C °F
40 104
35 95
30 86
25 77
20 68
15 59
10 50
Wet-bulb temperature
Sedentary man (60 W/m2)
0.6 clo units
100% RH
80% RH
60% RH
40% RH
20% RH
Effective temperature
35°
30°
25°
20°
Failure of physiologic temperature regulation
Comfort Zone
SC
N
SW
20 68
25 77
30 86
35 95
40 104
45 113 °F
°C
Dry-bulb Temperature